Comment on "Two Distinct Quasifission Modes in the ^{32}S+^{232}Th Reaction" (by D.J.Hinde et al. PRL 101, 092701 (2008))

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PACS numbers: PACS:25.70.Jj, 25.70.Gh

In a recent Letter [1], D.J.Hinde *et al.* presented comprehensive measurements of fission-type cross sections, angular anisotropies, mass distributions, and mass-angle distributions for the ^{32}S+^{232}Th reaction at various bombarding energies. One of the interesting conclusions of this Letter is that the quasifission (QF) dominates in the formation of more mass-symmetric component in the mass distribution. This conclusion partly arises from the comparison with the prediction of the transition state model. Although the decisive role of QF for the mass-symmetric part of the mass distribution was theoretically predicted in Refs. [3, 4], the experimental arguments, in our opinion, are still insufficient.

Similar mass-angle distributions were measured already long time ago and the correlation of the fragment mass with angle was seen as well, for example in Refs. [2]. In Refs. [2] the triple-differential cross sections, $d^3\sigma/dAd\theta_{c.m.}dTKE$, were obtained for the binary events within the full range of mass A and total kinetic energies (TKE) and within almost the full range of the center-of-mass angle $\theta_{c.m.}$. In Refs. [2] an observed distinct dependence between fragment mass and scattering angle shows that new reaction channel comes into play, namely the quasifission process. The central feature of this reaction mechanism is the evolution of the reaction complex towards mass symmetry. The experiments of Refs. [2] in 1984-1987 seem to be more informative than the experiment in Ref. [1], because in Ref. [1] the TKE of fragments is not presented and the experimental uncertainties of the separation of quasifission events from quasi-elastic and deep inelastic events for the mass asymmetric component are not discussed.

The systematical experimental study of the reactions with various charge asymmetries in the entrance channel but with the same total charge number is required to conclude reliably on the role of QF in the formation of mass-symmetric part of the mass (charge) distribution. The role of QF seems to be strongly increased with decreasing charge asymmetry in the entrance channel of the reaction [5, 6]. One can compare the mass (charge) and mass-angle distributions measured in reactions ^{16}O+^{249}Cf, ^{20}Ne+^{245}Cm, ^{32}S+^{232}Th, ^{40}Ar+^{226}Ra, ^{54}Cr+^{208}Pb, ^{64}Ni+^{198}Pt, ^{70}Zn+^{192}Os, and ^{76}Ge+^{186}W which all lead to almost the same compound nuclei. The reaction combinations with large and small charge asymmetries would have different characteristics of fission-type products. Comparing the yields of near-symmetric mass splits and the evaporation residue cross sections in the reactions, for example, ^{54}Cr+^{208}Pb and ^{64}Ni+^{198}Pt, one can unambiguously separate the fusion-fission and QF processes. The comparison of the small yields of the products with $Z = 6 - 16$ in the ^{54}Cr+^{208}Pb and ^{64}Ni+^{198}Pt reactions can give the complementary information [3] about the QF process.

The authors of Letter [1] wrote that "With the present lack of a realistic dynamical model of QF with arbitrary oriented deformed fragments, only qualitative explanations for the two distinct QF components can be proposed". In our opinion this statement is not correct and misleads readers. In Refs.[3, 4, 7] the dynamical models were suggested to describe the properties of quasifission. As follows from Ref.[3] (see Table I) and from Ref.[4], the QF mainly contributes to the formation of mass-symmetric component that is in agreement with the conclusions (iv)–(vi) of Letter [1].

As follows from the conclusion (iii) [1], the compact antialigned contact configuration, which is formed with larger probability at energies larger than the value of the Coulomb barrier, is more favorable for fusion and because of this the probability of asymmetric QF component decreases. However, the Fig. 3 of Letter [1] and the conclusions (iv)–(vi) result that the probability of QF symmetric component grows with increasing bombarding energy. It is clear that the increase of the relative contribution of the fusion-fission with respect to the QF should influence by the same way on symmetric and asymmetric components. So, the conclusion (iii) is not well justified.

In Ref. [3] the experimental energy distribution of quasifission fragments were analysed to find the most probable orientation of the nuclei in the dinuclear system. The orientation of the nuclei seems to be important for the capture stage and the formation of initial dinuclear system. However, the maximum of energy distribution of mass-symmetric component weakly depends on the bombarding energy and, thus, on the orientation of nuclei in the entrance channel. The authors of Ref. [1] discussed much the orientation effect in the entrance channel but they did not present the TKE of fragments.

In our opinion the maximum in the asymmetric mass yields arises from the minima on the potential energy surface and is caused by the shell effects around nuclei ^{208}Pb and ^{66}Ni. For low excitation energy, the evolution of the dinuclear system towards symmetry is hindered by these minima. With increasing excitation or bombarding energy the mass flow towards symmetry increases and the fractional yield of mass-asymmetric component

falls but the fractional yield of mass-symmetric component growths. Since at the same time the fusion probability grows, we have only the redistribution of mass-asymmetric and -symmetric QF components vanishing the asymmetry of the mass distribution. Comparing the experimental mass distributions [2, 8] at different bombarding energies, one can see that the mass drift towards symmetry increases with $E_{\mathrm{c.m.}}$ smearing the asymmetric QF component. In order to separate the effects of deformation in the entrance channel from the shell effects of the potential energy surface, one can compare the QF products of the reactions having different (small and large) entrance channel deformation and forming the same compound nucleus in the complete fusion process: ^{40,48}Ca+^{152,144}Sm or ^{80,86}Kr+^{150,144}Sm.

[1] D.J.Hinde, R.du Rietz, M.Dasgupta, R.G.Thomas, L.R.Gasques, Phys.Rev.Lett. **101**, 092701 (2008).

[2] G.Guarino *et al.*, Nucl.Phys.A **424**, 157 (1984); J.Töke *et al.*, Nucl.Phys.A **440**, 327 (1985); W.Q.Shen *et al.*, Phys.Rev.C **36**, 115 (1987).

[3] G.G.Adamian, N.V.Antonenko, W.Scheid, Phys.Rev.C **68**, 034601 (2003).

[4] Y.Aritomo, M.Ohta, Nucl. Phys. A **744**, 3 (2004).

[5] N.V.Antonenko *et al.*, Phys.Rev.C **51** (1995) 2635; G.G.Adamian, N.V.Antonenko, W.Scheid, V.V.Volkov, Nucl.Phys.A **627**, 361 (1997); **633**, 409 (1998); G.G.Adamian, N.V.Antonenko, W.Scheid, Nucl.Phys.A **678**, 24 (2000).

[6] D.J.Hinde, M.Dasgupta, A.Mukherjee, Phys.Rev.Lett. **89**, 282701 (2002).

[7] A.Diaz-Torres, G.G.Adamian, N.V.Antonenko, W.Scheid, Phys.Rev.C **64**, 024604 (2001); Nucl.Phys.A **679**, 410 (2001); A.K. Nasirov *et al.*, Eur.Phys.J.A **34**, 325 (2007).

[8] P.Gippner *et al.*, Z.Phys.A **325**, 335 (1986); G.N.Knyazheva *et al.*, Phys.Rev.C **75**, 064602 (2007); M.G.Itkis *et al.*, Nucl.Phys.A **787**, 150c (2007).